F E A T U R E

Plant Genetic Resources

The third paragraph of this article was updated to reflect new information received after publication. Please see www.ers.usda.gov/Amberwaves/June03/Features/PlantGeneticResources.htm for the latest information.

New Rules for International Exchange

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Botanist David Williams, with the International Plant Genetic Resources Institute in Cali, Colombia, receives a peanut landrace from a native farmer in the Amazonian lowlands of Ecuador.

Photo by Karen Williams, USDA/ARS

All crops, whether traditional varieties selected and harvested by farmers or modern varieties bred by professional plant breeders, descend from wild and improved genetic resources (also called germplasm) collected around the world. Plant selection and breeding do not end once an improved variety is achieved because the challenges facing crop production—pests, pathogens, and climates—constantly evolve and change. To make crops more resistant to pests and diseases and to improve food supply quality, quantity, and variety, modern plant breeders continually seek genetic resources from outside the stocks with which they routinely work.

Since no nation has within its borders the desired spectrum of genetic resources, international collection and exchange occurs. Not all participants in this exchange, however, view the benefits as fairly balanced between donors and recipients. Another issue is that valuable genetic resources not yet collected and preserved may be endangered by land use changes in some countries.

To address these issues, delegates from 116 countries voted in November 2001 to adopt the text of a new United Nations International Treaty on Plant Genetic Resources for Food and Agriculture. When ratified or acceded to by 40 countries (17 have done so to date), the new treaty will enter into force and govern the international exchange of designated crop genetic resources. It will also attempt to resolve longstanding issues over how the benefits derived from the use of genetic resources are shared.

The success of the new treaty will depend to a great extent on whether its provisions actually facilitate international exchange and whether expectations are met concerning benefits sharing. When implemented, the treaty will affect the U.S., which has one of the largest national germplasm collections in the world and the largest national investment in plant breeding.

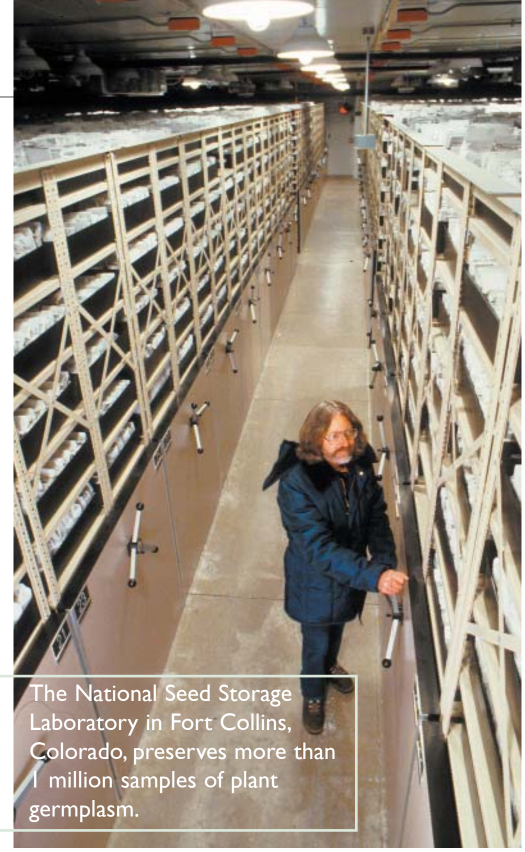
Why Is Germplasm Important?

The relationship between access to genetic resources and agricultural production is often overlooked. The plant breeding process is complex and continual, and diverse genetic resources are a critical input. Advances in yield potential, pest resistance, quality, and other desirable traits in modern varieties have resulted from professional breeders crossing diverse parental genetic material. Farmers who rely on their crop output for seed or consumption and professional plant breeders both depend on crop genetic resources. In turn, the efforts of farmers and plant breeders can generate new genetic resources.

About 10,000 years ago, people in parts of Asia, the Near East, and Mesoamerica (modern-day Mexico and Central America) began to deliberately cultivate specific species. Over the generations, farmers selected and improved particular crops. In many parts of the world, this process continues today with farmer-developed varieties known as landraces (see box "Types of Germplasm"). Landraces have been adapted to specific environments, and the areas in which they grow host many diverse varieties.

The places of initial domestication of different crops are called "centers of origin," many of which are in today's developing countries (see map, opposite page). Most crops of major economic importance to the U.S. originated elsewhere. In addition, genetic resources from around the world continue to play a critical role in maintaining varietal improvement in U.S.-produced crops (see box "Modern Plant Breeding"). For example, the genes that provide resistance to yellow dwarf disease in U.S. barley varieties were obtained from Ethiopia. The sources of resistance to stem rust disease for U.S. commercial wheat varieties include a wild plant originating in the Caucasus and a Spanish durum landrace.

The U.S. is also a leading participant in the international collection and exchange of crop genetic resources. Holdings in the U.S. National Plant Germplasm System (NPGS) exceed 450,000 accessions, comprising 10,000 species of the 85 most commonly grown crops, making the U.S. system one of the largest national gene banks in the world. NPGS includes publicly funded collections located across the country as well as centralized facilities for plant exploration coordination, quarantine, and long-term germplasm storage. Although most of the NPGS germplasm is not native to the U.S., the costs of collecting and preserving



The National Seed Storage Laboratory in Fort Collins, Colorado, preserves more than 1 million samples of plant germplasm.

Photo by Scott Bauer, USDA/ARS

germplasm have been borne almost entirely by the U.S.

Although relatively few major crops originated in the U.S., sample collection efforts, extensive plant breeding, and germplasm regeneration have made the U.S. a net supplier of plant germplasm to the rest of the world. Between 1993 and 2002, NPGS sent more than 1.2 million samples to requestors free of charge, with 30 percent of the samples going to requestors in foreign countries. Overall, the U.S. distributed about seven times

Types of Germplasm

Advanced (or elite) germplasm includes 1) "cultivars," or cultivated varieties, which are suitable for planting by farmers, either recently developed cultivars or "obsolete" cultivars that are no longer grown, and 2) advanced breeding material that breeders combine to produce new cultivars (sometimes referred to as "breeding materials").

Improved germplasm is any plant material containing one or more traits of interest that have been incorporated by scientific selection or planned crossing.

Modern dent corn, U.S.

Landraces are varieties of crops improved by farmers over many generations without the use of modern breeding techniques. Within a modern breeding program, landraces are sometimes used for resistance traits, and extensive efforts are generally required before their genes can be used in a final variety.

Current maize landraces, central Mexican highlands. Photo by Hugh Iltis

Centers of origin of selected crops

Note: The pointer locations indicate general regions where crops are believed to have first been domesticated. In some cases, the center of origin is uncertain. Other geographic regions also harbor important genetic diversity for these crops.

Source: This map was developed by the General Accounting Office using data provided by the National Plant Germplasm System's Plant Exchange Office.

Wild or weedy relatives are plants that share a common ancestry with a crop species but have not been domesticated. These plants can serve as another source of resistance traits, but these traits can be very difficult to incorporate in final varieties.

Teosinte (possible maize ancestor) and reconstructed possible early maize ear.
Photo by John Doebley

Genetic stocks are mutants or other germplasm with genetic abnormalities that may be used by plant breeders for specific purposes. Genetic stocks are often used for highly sophisticated breeding and basic research.

Photo provided by the Maize Genetics Cooperation--Stock Center, NPGS, supported by USDA/ARS.

Modern Plant Breeding

Generally, plant breeders prefer to work with existing cultivars or advanced breeding materials (sometimes called elite materials) because these adapted sources of material are already highly productive and relatively easy to intermate. But because pests and diseases evolve over time, breeders continually need new and diverse germplasm from outside the standard gene pool to find specific traits to maintain or improve yields. Sometimes as a last resort, breeders rely on landraces and wild relatives of crops, but these generally carry unwanted traits that are linked with a desirable trait's gene, making it difficult to incorporate the trait into high-yielding cultivars. When used, however, genes from landraces or wild relatives often have had disproportionately large and beneficial impacts. Some breeders also seek and use traits and information from "genetic stocks," which include mutants and other germplasm with genetic abnormalities.

The advent of biotechnology may expand the scope of desired traits that can be incorporated in new varieties. The use of biotechnological techniques, such as molecular markers, may make it easier to incorporate the beneficial characteristics of landraces and wild relatives of agricultural crops. Biotechnology also can be used to incorporate traits from very disparate species. The challenges of developing pest and disease resistance and improvements in yield potential remain the same regardless of whether a plant is conventionally bred or bioengineered.

more germplasm internationally than it received from international sources between 1990 and 1995. Such international germplasm transfers, as well as new international acquisitions, may be subject to the provisions of the new treaty after it enters into force.

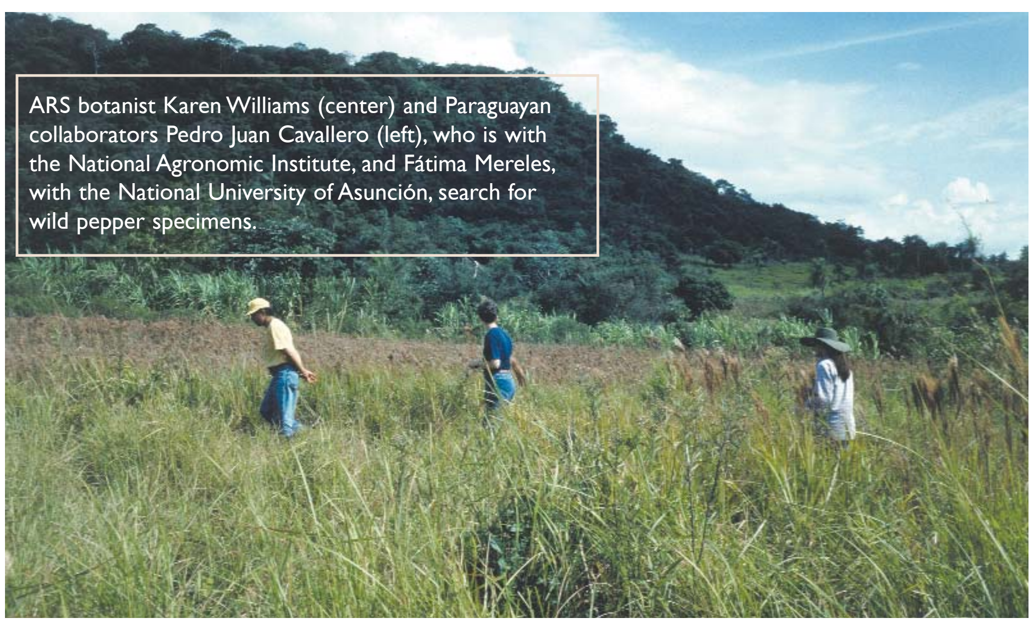
Besides the number of samples distributed, another significant contribution of NPGS is the breadth of material provided, which includes landraces, wild relatives, and genetic stocks. NPGS has also added to the improved germplasm accessible to international breeders. More than 40 percent of the U.S. samples distributed internationally in 1990-95 were advanced or improved materials "created" through research and breeding.

International Issues and Agreements

Historically, plant genetic material was generally freely collected and shared. Today's developing countries—with a wealth of biological diversity in situ (in the wild and on fields)—were often the source of raw genetic material collected by public gene banks worldwide.

Now, however, critics argue that unrestricted access to germplasm unaccompanied by benefit sharing results in an inequitable system of exchange. For example, freely shared crop traits from donor countries could be incorporated into varieties by researchers in developed countries and then sold back to donor country farmers by private seed companies. The lack of direct compensation is seen as giving donor countries little incentive to conserve genetic resources, some of which are now at risk of extinction. Proponents counter that a system of "free exchange" indirectly compensates lower income countries for donations of raw genetic materials in two ways. First, these countries have had free access to public gene banks, whose holdings include improved varieties. Second, many lower income countries are net importers of food, and consumers in those countries benefit from lower world food prices made possible by genetic improvements, regardless of where the improvements were made.

Several international agreements have sought to further the preservation of genetic resources and to balance the sharing of benefits generated by their use. In 1983, the Commission on Plant Genetic Resources (now the Commission on Genetic Resources for Food and

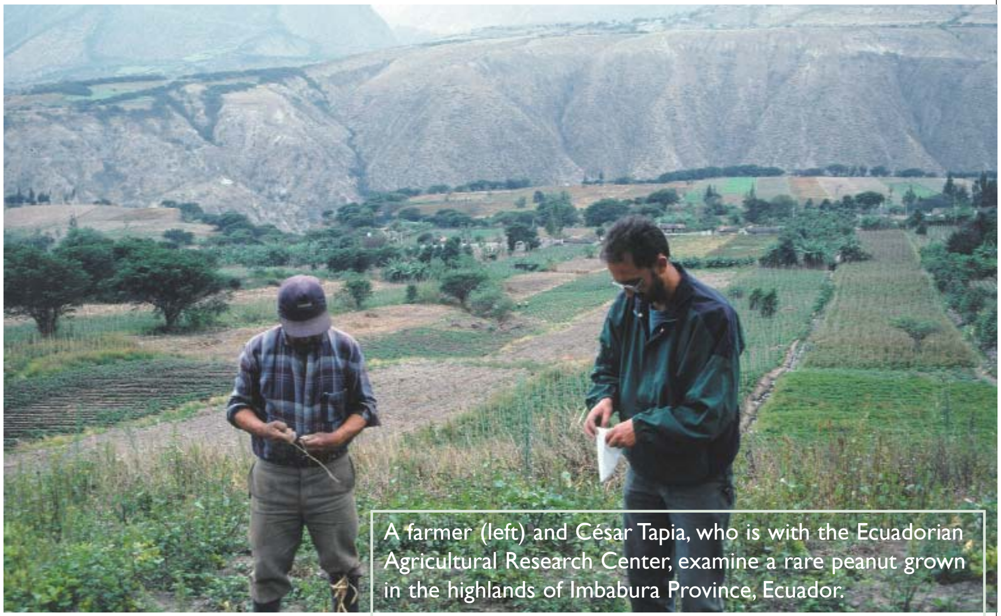


ARS botanist Karen Williams (center) and Paraguayan collaborators Pedro Juan Cavallero (left), who is with the National Agronomic Institute, and Fátima Mereles, with the National University of Asunción, search for wild pepper specimens.

Photo by David Williams, USDA/ARS

Agriculture) was established under the auspices of the Food and Agricultural Organization (FAO) of the United Nations. The Commission developed the International Undertaking, a nonbinding treaty to govern the exchange of genetic resources, but some developing and developed countries (including the U.S.) did not commit to its implementation. In 1992, the U.N. Convention on Biological Diversity (CBD) was established, with a focus on the preservation of biodiversity, especially those genetic resources with pharmaceutical and industrial rather than agricultural uses. In an attempt to ensure equitable returns to donor countries for the use of native resources (and to spur conservation), the CBD granted nations sovereign rights to genetic resources within their borders, which in practice meant both nonagricultural and agricultural germplasm. The U.S. has signed, but not yet ratified, the CBD.

International agreements on intellectual property rights also have implications for genetic resource conservation. Stronger intellectual property rights provide incentives for private research and development (R&D) investment, and, in theory, also enhance incentives for conserving genetic resources. However, intellectual property law varies from country to country and may not cover unimproved germplasm and farmer-developed varieties. The World Trade Organization's (WTO) agreement on Trade-Related Aspects of Intellectual Property Rights has provisions that can affect the exchange of germplasm. WTO member countries must commit to implementing a system protecting intellectual property for plant genetic resources, and noncompliance can result in sanctions.



A farmer (left) and César Tapia, who is with the Ecuadorian Agricultural Research Center, examine a rare peanut grown in the highlands of Imbabura Province, Ecuador.

Photo by Karen Williams, USDA/ARS

The New Treaty

The new International Treaty on Plant Genetic Resources for Food and Agriculture was intended to bring the International Undertaking into conformity with the CBD. After lengthy negotiations, delegates from 116 countries adopted the text of the treaty in November 2001, with the American and Japanese delegates abstaining. The U.S. signed the treaty in November 2002, but ratification will require the State Department to submit the treaty to Congress for approval.

The new treaty has several objectives. First, it mandates the conservation and sustainable use of plant genetic resources

Crops covered under the International Treaty on Plant Genetic Resources for Food and Agriculture

Apple
Major aroids: includes taro, cocoyam, dasheen, and tannia
Asparagus
Banana/Plantain
Barley
Bean
Beet
Brassica complex: includes cabbage, rapeseed, mustard, cress, rocket, radish, and turnip
Breadfruit
Carrot
Cassava
Chickpea
Citrus
Coconut
Cowpea
Eggplant
Faba bean / Vetch
Finger millet
Grass pea
Lentil
Maize (corn)
Oat
Pea
Pearl millet
Pigeon pea
Potato
Rice
Rye
Sorghum
Strawberry
Sunflower
Sweet potato
Triticale
Wheat
Yam

Forages
15 genera of legume forages
12 genera of grass forages
2 genera of other forage

Rice germplasm from the Philippines is monitored for fungal diseases before release to U.S. breeders.

USDA/ARS photo

for food and agriculture. Second, it seeks fair and equitable sharing of benefits arising out of the use of these resources. Finally, it establishes a multilateral system to facilitate access to all crops listed in Annexes I and II of the treaty (see box "Crops covered under the International Treaty...") and to share the benefits derived from such facilitated access under the terms of a standard Material Transfer Agreement (MTA). The treaty specifies that the terms of the standard MTA will be established by the Governing Body at its first meeting after the treaty enters into force.

Much remains to be resolved. Application of intellectual property rights to plant genetic resources remains a contentious issue. Precisely how benefits will be shared has yet to be determined and is complicated by:

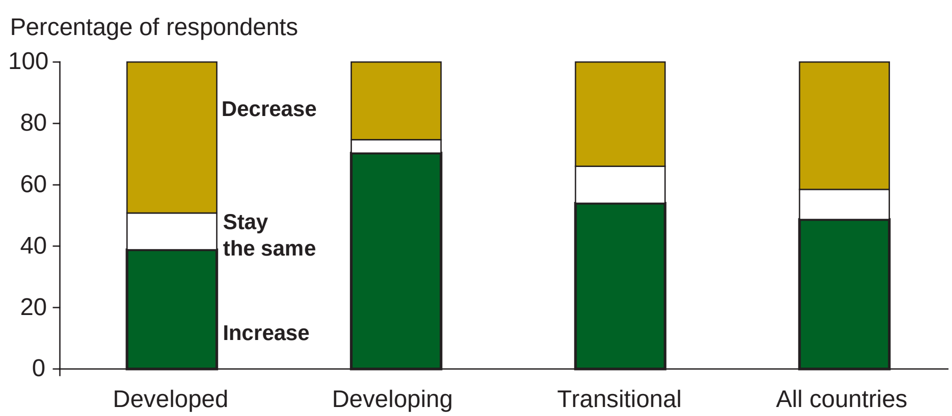
- A lack of consensus regarding what "equitable" benefit sharing means.
- Disagreement over how to estimate the magnitude of benefits derived from use of shared germplasm.
- Substantial variability in benefit estimates derived from similar assessment methods.

Unlike the CBD, which provides for bilateral negotiations to establish the terms of access and benefit sharing for each specific exchange of materials, all germplasm exchanges under the multilateral system will be subject to the standard MTA. Monetary benefits will be paid to a fund established by the Governing Body. This fund will be used primarily to support farmers who conserve and sustainably use plant genetic resources for food and agriculture, especially such farmers in developing countries or in countries with economies in transition.

In October 2002, the FAO Commission on Genetic Resources for Food and Agriculture, in its capacity as the interim committee of the treaty, agreed to establish an Expert Group to develop and propose recommendations on the terms of the standard MTA. The Expert Group will include representatives from each FAO region and will provide advice on the level, form, and manner of benefit-sharing payments. They will also make recommendations regarding the level of payments to be made by various categories of recipients and the conditions under which recipients may be exempt from making payments. The first meeting of the Expert Group is tentatively scheduled for summer 2003.

The new treaty addresses the financing of germplasm conservation only in general terms, making this aspect of the treaty potentially difficult to implement. The overall impact of the treaty is also limited by its omission of soybeans, peanuts, and

International demand for U.S. germplasm is expected to be strong over the next decade, especially in developing countries



Based on responses of international recipients of U.S. germplasm to questions regarding their expected future use.

Source: Study conducted by International Plant Genetic Resources Institute.

Photo by Scott Bauer, USDA/ARS

Utility of NPGS Materials

A team of ERS, academic, and international researchers studied the utility of materials distributed internationally from 1995 to 1999 by the U.S. National Plant Germplasm System (NPGS), focusing on 10 major crops (barley, beans, corn, cotton, rice, potatoes, sorghum, soybean, squash, and wheat). International recipients indicated that 11 percent of the samples received during the 5-year period had already been incorporated into breeding programs in their respective countries. Another 42 percent of the received samples were still being evaluated and 19 percent had been useful in other ways, such as material for basic research, an often overlooked benefit. Only 28 percent of materials were reported to have been not useful by the respondents. Recipients in developing countries found NPGS materials especially useful, reporting that 16 percent of the germplasm samples had already been used in breeding programs, about three times the share reported by respondents in developed and transitional economies.

Original recipients of NPGS germplasm can distribute that germplasm to additional users, generating secondary benefits. International recipients shared an estimated 18 percent of all NPGS germplasm samples with users within their own institutions and 10 percent with users at other institutions.

In addition to the NPGS germplasm itself, data about the germplasm, when available, also provide benefits. For example, data on a sample's varietal characteristics and yield can speed the research and breeding process. For the 10 crops in the study, respondents reported that 28 percent of NPGS samples had data for the trait they were specifically seeking, and 18 percent had data useful for other purposes.

other major world crops from the list of 35 crops covered (see box "Crops covered under the International Treaty...").

Future International Reliance on Germplasm Exchange

As the new treaty is implemented, much of the focus will be on how countries can reap the benefits of their genetic resource holdings. However, the returns generated by any one set of genetic resources are very uncertain and, given the lengthy time associated with plant breeding, such returns are not likely to be realized quickly. Far more certain is the critical role that genetic resources play in the breeding process. Few countries are germplasm-rich with respect to all their major crops. Dependence on genetic resources from other nations is a significant factor for developed and developing countries alike.

Expectations of international recipients of NPGS germplasm provide some indication of future demand for public germplasm. According to a study by ERS, academic, and international researchers, most international recipients expected their demand for NPGS resources to increase or stay the same (see box "Utility of NPGS Materials"). A higher share of recipients in developing countries indicated they would increase their requests from the NPGS in the next decade than did recipients from either developed or transitional economies.

Because the NPGS plays such a significant role in providing germplasm worldwide, the U.S. has assumed a responsibility not only to its own crop breeders, but also to crop breeders throughout the world. Since NPGS genetic resources are particularly valuable to developing countries, given their limited funds for germplasm management, the provisions of the International Treaty have the potential to affect users of U.S. germplasm far beyond this country's borders. At the same time, the treaty could also affect the international exchange of diverse germplasm needed by plant breeders to maintain and improve U.S. crops in the future. W

This article is drawn from. . .

The Demand for Crop Genetic Resources: International Use of the U.S. National Plant Germplasm System, by M. Smale, and K. Day-Rubenstein, *World Development*, Vol. 30, No. 9, 2002; an earlier version is available at: www.ifpri.org/divs/eptd/dp/eptdp82.htm

"ARS is Banking on Germplasm," by David Elstein, in *Agricultural Research*, February 2003, available at: www.ars.usda.gov/is/AR/archive/feb03/germ0203

International Treaty on Plant Genetic Resources for Food and Agriculture, available at: www.fao.org/cpgrfa